GRID MODERNIZATION INITIATIVE
PEER REVIEW
GMLC 1.1 – Metrics Analysis

MICHAEL KINTNER-MEYER (PNNL)
April 18-20, 2017
Sheraton Pentagon City – Arlington, VA
Basic Definitions

**Reliability**
The uninterrupted delivery of electricity with acceptable power quality to meet electricity users’ needs for—or applications of—energy.

**Resilience**
The ability to prepare for and adapt to changing conditions and to withstand and recover rapidly from low-probability, high consequence disruptions.

**Flexibility**
The ability of a power system to respond to changes in supply and demand. Flexibility metrics are critical for integration of renewable generation.

**Sustainability**
Defined as having three pillars—environmental, social, and economic—this project focuses on sustainability factors associated with greenhouse gas emissions though other pollutants and media were considered, e.g. land, water, etc.

**Affordability**
The customer’s cost of electric service as a proportion of their income or business revenue.

**Security**
The ability to reduce risk to critical infrastructure by reducing vulnerability to physical and cyber-attacks or natural disasters.
Primary Objectives and Goals

Reliability
- Directly include the economic costs borne by customers when their power is interrupted - the value of reliability – in reliability decision making
- Improve overall measure of bulk power system health
- Probabilistic enhancement of transmission planning metrics

Flexibility
- Capture the current landscape of metrics being used in various markets to express flexibility demand, supply, and the balance between supply and demand
- Methodologies and approaches for system planning and assessing recent events

Affordability
- Propose metrics that determine the electricity service cost burden affecting end-use customers or “what portion of customers’ income or revenue is required to pay for electricity service?”

Resilience
- Help utilities better plan for and respond to low-probability, high-consequence disruptive events that are not currently addressed in reliability metrics and analyses.
- Provide an effective, precise, and consistent means for utilities and regulators to communicate about resilience issues.

Sustainability
- Examine how national GHG metrics and reporting procedures may need to be modified to assess changes in the environmental sustainability as the grid evolves, particularly, as new distributed resources are being deployed.

Security
- Develop a framework that is consistent and repeatable across all utilities while maintaining flexibility to account for organization of facility security objectives given their specific threat landscape and security priorities.
<table>
<thead>
<tr>
<th>Metric Category</th>
<th>Example Metrics</th>
<th>Lagging/Leading</th>
<th>Approach</th>
<th>Testbeds/Partners</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reliability - Distribution</td>
<td>More spatially and temporally granular than SAIDI and SAIFI - which customers affected and duration of outages</td>
<td>Lagging</td>
<td>Enhancement of existing metrics</td>
<td>APPA, Idaho RPP</td>
</tr>
<tr>
<td>Reliability — Bulk power system</td>
<td>Supplementing TADS and GADS with contextual information about the transmission networks within which the outages occurred to understand the impact or severity of an outage wrt overall system reliability</td>
<td>Lagging</td>
<td>Enhancement of existing metrics</td>
<td>NERC – State of Reliability report</td>
</tr>
<tr>
<td>Reliability — Transmission Planning</td>
<td>Enhance the existing deterministic transmission planning metrics such as loss of load and voltage violation to probabilistic metrics, i.e., by associating each of the metrics with a probabilistic distribution determined by the distributions of frequencies and durations of the individual contingencies.</td>
<td>Leading</td>
<td>Developing a generic approach for parameterizing common mode outages (e.g. wind gen. based on correlation of wind generation data in different locations); may use enhanced Python-driven PSS/E-based enhanced PCA tool</td>
<td>ERCOT, NE-ISO, Idaho Power</td>
</tr>
</tbody>
</table>
## Metric Category Details

<table>
<thead>
<tr>
<th>Metric Category</th>
<th>Example Metrics</th>
<th>Lagging/Leading</th>
<th>Approach</th>
<th>Testbeds/Partners</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Security</strong></td>
<td>Physical Security – fences, gates, CCT, barriers, etc. Security Management Security Force – staffing, equipment, training, etc. Information Sharing Security Activity Background – prior vulnerability and new protective measures</td>
<td>lagging</td>
<td>Replicates DHS Protective Measure Index methodology with a subset of survey questions and publicly available datasets; Benchmarking capability</td>
<td>ComEd; Exelon utilities; DHS, NASEO, NRRI, EPRI, EEI,</td>
</tr>
<tr>
<td><strong>Affordability</strong></td>
<td>Household electricity burden Household electricity affordability gap Household electricity affordability gap index Household electricity affordability headcount index Annual average customer cost Average customer cost index.</td>
<td>lagging</td>
<td>Uses publicly available datasets (EIA-RECS, Census) to calculate cost burden for electric end-use customer; could enhance precision with more granular electric bill and income data.</td>
<td>Alaska RPP, CO Energy Office, California, WA UTC,</td>
</tr>
<tr>
<td><strong>Resilience</strong></td>
<td>Cumulative customer-hours of outages; Cumulative customer energy demand not served; Ave. # (or %) of customers experiencing an outage during a specified time period; Critical customer energy demand not served; Average # (or %) of critical loads that experience an outage Time to recovery; Cost of recovery; Loss of utility revenue; Cost of grid damages (e.g., repair or replace lines, transformers); Cost of recovery; Avoided outage cost</td>
<td>leading</td>
<td>Development of new framework for performance and consequence-based resilience metrics; could include historical data such as utility OMS systems and/or Monte Carlo simulations with power flow models, etc.</td>
<td>New Orleans, Entergy, DHS, PJM, AEP, NJ Transit, EPRI, NARUC,</td>
</tr>
<tr>
<td>Metric Category</td>
<td>Example Metrics</td>
<td>Lagging/Leading</td>
<td>Approach</td>
<td>Testbeds/Partners</td>
</tr>
<tr>
<td>-----------------</td>
<td>-----------------</td>
<td>-----------------</td>
<td>----------</td>
<td>------------------</td>
</tr>
<tr>
<td>Flexibility</td>
<td>Loss of load; Insufficient ramping Flexibility ratio; Wind generation Solar generation fraction; Wind/solar generation volatility; Net load forecasting error; Net load factor; Max. ramp rate in net load; Max. ramp capacity; Energy storage available; Demand response capability; Inter-regional or Intra-regional transfer capability; Interruptible tariffs; RE curtailment; Negative LMP; Price spikes Load shedding; Operational reserve shortage; Control performance (CPSs 1. 2; BAAL); Out-of-market operations; LOLE_flex; LOLE_multihour, IRRE</td>
<td>Leading and lagging</td>
<td>• Planning metrics (leading) – focused on <em>production cost modeling</em>; • Examining recent events (lagging) – analysis of various datasets with statistical or econometric techniques</td>
<td>PG&amp;E, CAISO, ERCOT, EPRI, FERC</td>
</tr>
<tr>
<td>Sustainability</td>
<td>Primarily focused on CO\textsubscript{2}, though some reports also include N\textsubscript{2}O, CH\textsubscript{4}, HFCs, PFCs, SF\textsubscript{6}, NF\textsubscript{3}, and other GHGs</td>
<td>lagging</td>
<td>• Examined the current reporting processes, sources of data and ability to capture GHGs from emerging energy sources</td>
<td>EPRI, EPA, EIA, ASU, NRRI, SASB</td>
</tr>
</tbody>
</table>
Potential Pathway for National-Scale Metrics Development

Example Pathway: 

**Flexibility**

**Y1:** 
- Mapping of Landscape and Methods 
- Input from Partners 
- Socialize with potential data org’s - EIA and FERC

**Y2/3:** 
- Refinement of Metrics and Methods; 
- Testing with two ISOs 
- Share results from testing and refined metrics 
- Socialize with member org’s, e.g. EPRI, RTO Council 
- Identify opportunities with data org’s – EIA and FERC 
- Publish results and final set of metrics

**Y4/5/beyond:** 
- Documented use of metrics to make investment and market design decisions by multiple system operators, national/state regulators, and/or utilities 
- Incorporation of specific metrics into national survey reports, e.g. EIA, FERC
Project Description
The objective of the project is to assess the feasibility and usefulness of metrics for measuring change in the evolving electricity infrastructure. Metrics and associated methods will be developed to assess the power grid’s evolution with respect to characteristics that are organized into the following 6 categories: reliability, resilience, flexibility, sustainability, affordability, and security.

Value Proposition
✓ Solving the lack of holistic and comprehensive set of metrics to:
  ✓ Express full value of grid investments
  ✓ Describe comprehensively multiple attributes of grid assets
✓ Audiences: investors; federal, state, municipal regulators; utilities; ISOs

Expected Outcomes
✓ Enhance existing metrics to enable DOE to better set priorities on modernization R&D
✓ Report on metrics definition and approaches and baseline
✓ Validation of metrics and approaches with stakeholders and regional partners
✓ Adoption of metrics by key partners
Project Participants and Roles

ANL – Security and synthesis lead, resilience contributor
BNL – Reliability contributor
LANL – Synthesis contributor
LBNL – Reliability lead
LLNL – Flexibility lead
NREL – Sustainability and stakeholder engagement lead, flexibility contributor
ORNL – Affordability contributor
PNNL – Affordability lead and project manager
SNL – Resilience lead

Working Partners

APPA: REL
DHS: RES, SEC
EIA: SUS
EPA: SUS
EPRI: RES, FLE, SUS, AFF
FERC: FLE
NARUC: SEC
NERC: REL
ERCOT: FLE
CAISO: FLE
WA-UTC: AFF
Col. State Energy Office: AFF
NASEO: SEC
EEI: SEC
PG&E: FLE
City of New Orleans: RES
Alaska: AFF

PROJECT FUNDING

<table>
<thead>
<tr>
<th>Lab</th>
<th>FY16 ($)</th>
<th>FY17 ($)</th>
<th>FY18 ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANL</td>
<td>206</td>
<td>62.5</td>
<td>57.5</td>
</tr>
<tr>
<td>BNL</td>
<td>57</td>
<td>7.5</td>
<td>7.5</td>
</tr>
<tr>
<td>LANL</td>
<td>27</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>LBNL</td>
<td>226</td>
<td>42.5</td>
<td>42.5</td>
</tr>
<tr>
<td>LLNL</td>
<td>146</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td>NREL</td>
<td>333</td>
<td>102.5</td>
<td>97.5</td>
</tr>
<tr>
<td>ORNL</td>
<td>70</td>
<td>12.5</td>
<td>12.5</td>
</tr>
<tr>
<td>PNNL</td>
<td>343</td>
<td>215</td>
<td>235</td>
</tr>
<tr>
<td>SNL</td>
<td>173</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td>Reserve</td>
<td>1072</td>
<td>1061.5</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1581</td>
<td>1584.5</td>
<td>1584</td>
</tr>
</tbody>
</table>

It is also directly aligned with MYPP with other multiple areas:

- Devices and integrated system testing
- System operation, power flow, and control
- Design and planning tools
- Security and Resilience

GMLC1.1: Develop new comprehensive set of metrics to track grid modernization
GMLC1.1: Metrics Analysis

Approach

Engage Stakeholders for Need/Value Assessment and Validation of Metrics

Stakeholder Advisory Group (SAG):
- Federal, State, Municipal Regulators
- Utilities
- ISOs, RTOs
- Industry associations

Establish Methodology for Monitoring Progress of Grid Modernization

Document and Disseminate Metrics for Broad Adoption

Reference Document defines new metrics and processes

Adoption of Metrics through existing channels (EPA, EIA, IEEE standards, best practice)

Active outreach to stakeholder groups

Collaboration with GMLC Portfolio researchers

Validate Metrics through Pilot Projects

GMLC Regional Partners will exercise individual and multiple metrics

Utilities will test metrics for self-assessment

Institutional Support

5/11/2017
## GMLC1.1: Metrics Analysis

### Key Project Milestones

<table>
<thead>
<tr>
<th>Milestone (FY16-FY18)</th>
<th>Status</th>
<th>Due Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Develop program plan and stakeholder engagement strategy</td>
<td>Completed June 30, 2016</td>
<td>June 30, 2016</td>
</tr>
<tr>
<td>Develop a booklet illustrating initial approach, methodologies, and data requirements</td>
<td>Completed – initial reference document with focus areas for each metrics category</td>
<td>June 30, 2016</td>
</tr>
<tr>
<td>Initial meetings with working partners</td>
<td>Completed – overview of project and Year 1 focus in each metric category</td>
<td>August 30, 2016</td>
</tr>
<tr>
<td>Plans in place for testing specific metrics</td>
<td>Ongoing – holding discussions GMI RP to identify pilots for each metric</td>
<td>December 31, 2016</td>
</tr>
<tr>
<td>Develop report with initial new metrics</td>
<td>Ongoing – specific deliverables and outline developed</td>
<td>March 2017</td>
</tr>
<tr>
<td>Revise program plan and communication strategy. This will make recommendations for budget allocations from reserve to topical areas</td>
<td>Not initiated</td>
<td>April 30, 2017</td>
</tr>
<tr>
<td>Final report documenting use case metrics applications</td>
<td>Not initiated</td>
<td>August 31, 2018</td>
</tr>
<tr>
<td>Briefing material for implementation of metrics in a web-based dashboard</td>
<td>Not initiated</td>
<td>August 31, 2018</td>
</tr>
</tbody>
</table>


GMLC1.1: Metrics Analysis
Accomplishments to Date

Reliability

New metrics for distribution to represent value-based planning

New metrics for system impacts using North American Electric Reliability Corporation transmission/generation availability data

Approach and tool for and demonstration of probabilistic enhancement of existing transmission planning metrics

Accomplishment

- APPA committed to use value-based outage metric
- Established process to be tested with New Orleans and NJ Transit Authority
GMLC1.1: Metrics Analysis
Accomplishments to Date

Flexibility
Developed large set of candidate metrics that represent network properties of flexibility and lack of flexibility, engaging stakeholders to identify most useful metrics

Lagging indicators
• Requires statistical analysis of market and grid conditions to reveal curtailments, loss of load, or other economic impacts caused by insufficient flexibility.

Leading indicators
• Requires production cost simulations with weather and other uncertainties to design for sufficient flexibility.
• Use production cost models to examine tradeoffs between different sources of flexibility.

Sustainability
Ability of federal greenhouse gas data products to capture changes in electric-sector CO₂ emissions that might result from future grid modernization varies, depending on coverage of certain energy sources anticipated to grow.

- Engagement with PG&E, CAISO, ERCOT to down-select leading indicators from large set of metrics

Accomplishment
- Determined coverage of DER in GHG reporting federal products
- How to address DER fully in GHG reporting
GMLC1.1: Metrics Analysis
Accomplishments to Date

**Accomplishment**
- Working with Colo. State Energy Office, WA UTC
- Test driving with Regional Partners: AL, New Orleans

- Working with ComEd, and Idaho Falls

**Cost Burden Metrics (emerging)**
- Customer electricity cost burden
- Electricity affordability gap
- Affordability gap headcount
- Temporal indices of these metrics

**Security**

**Protective Measures Index**
- Determines protective security posture of an entity.
- Initially developed for and applied by Department of Homeland Security (DHS).
- Stakeholder agreement for use as physical security metrics for Electric sector.
- Allows comparison of physical security posture for similar entities.
- Has been applied to 400-plus electric facilities.
1.2.4 Valuation Framework Development: providing integral support to this project by developing methods for prospective metrics (e.g., reliability, resilience, flexibility,) and process for weighing preferences for the various value attribute trade-offs

1.2.1 Grid Architecture: utilizing same definitions of terms and assuring compatibilities of metrics in emerging grid architectures

1.4.2 Device Characterization and Testing: assuring compatibilities in terminology for defining use-cases and duty cycles

1.2.25: Distribution System Decision Support: coordination processes in trade-off analyses between different outcomes expressed by metrics categories
GMLC1.1: Metrics Analysis
Next Steps and Future Plans

Use-cases and baselining (selected next steps)

**Affordability**
Baselining **lagging and leading** metrics with Alaska Villages

**Resilience**
Use-cases analysis with New Orleans validating the process for **leading** metrics

**Flexibility**
- Reducing the set of **lagging** metrics by statistical analysis (CAISO, ERCOT)
- Reducing the set of **leading** metrics by modeling (CAISO)

Coordination with other GMLC Projects

Valuation Project

- **Reliability**
- **Resilience**
- **Flexibility**
- **Sustainability**
- **Security**
- **Affordability**

Outreach and Dissemination
- Reference Document 3.0
- EPRI webinars
- High visibility event(??)

Implementation Plan in Year 3
- Identifying who will own metrics
- who will have access to data
## GMLC1.1: Metrics Analysis
Response to December 2016 Program Review

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Please provide a baseline and measuring success: During development of the lab</td>
<td>Baseline approach established in the Reference Document 2.0 (March 31, 2017)</td>
</tr>
<tr>
<td>call, this project was designed to help identify and clearly define key</td>
<td></td>
</tr>
<tr>
<td>metrics for the grid that could be used to provide a baseline for regions of</td>
<td></td>
</tr>
<tr>
<td>the country. As DOE, utilities, and others implemented demonstrations on the</td>
<td></td>
</tr>
<tr>
<td>grid, these metrics could be used to measure improvement (or decline) in these</td>
<td></td>
</tr>
<tr>
<td>basic grid attributes. This feature cannot be lost.</td>
<td></td>
</tr>
<tr>
<td>Please identify the customer: These metrics need to have value both internally</td>
<td>each metric area will have different customers. There is not single</td>
</tr>
<tr>
<td>(within DOE and the labs), but they must have legitimacy to outside stakeholders</td>
<td>customer for metrics in all 6 metrics areas</td>
</tr>
<tr>
<td>as well. It is understood that finding legitimacy across a broad set of</td>
<td>We will address specific users in the next version of Reference Document</td>
</tr>
<tr>
<td>stakeholders is difficult.</td>
<td></td>
</tr>
<tr>
<td>Please prioritize: Within world of limited resources, how does DOE and the</td>
<td>The labs consulted with stakeholders to guage value of each metric area.</td>
</tr>
<tr>
<td>labs prioritize funding across these metrics? Some are more mature than others</td>
<td>Labs and DOE will determine in Year 2 what the prioritization will be.</td>
</tr>
<tr>
<td>. How does DOE and the labs consider a need for new metrics not covered today?</td>
<td>Labs will propose prioritization to be discussed and approved by DOE.</td>
</tr>
</tbody>
</table>
### Affordability Baselining: Alaska Villages

<table>
<thead>
<tr>
<th>Village</th>
<th>Average Proportion of Income Spent on Electricity (Customer Burden)</th>
<th>Affordability Gap Factor @ 3% Threshold</th>
<th>Affordability Gap Index (2010=1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chefornak</td>
<td>3.21%</td>
<td>3.00%</td>
<td>2.68%</td>
</tr>
<tr>
<td>Shungnak</td>
<td>4.28%</td>
<td>3.69%</td>
<td>3.71%</td>
</tr>
<tr>
<td>AK Villages Weighted Average</td>
<td>3.08%</td>
<td>3.03%</td>
<td>3.01%</td>
</tr>
</tbody>
</table>

### Village Summary

<table>
<thead>
<tr>
<th>Village</th>
<th>Percent of HH with Unaffordable Electricity</th>
<th>Affordability Headcount Gap Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chefornak</td>
<td>38.0%</td>
<td>36.1%</td>
</tr>
<tr>
<td>Shungnak</td>
<td>44.4%</td>
<td>40.3%</td>
</tr>
<tr>
<td>AK Villages Weighted Average</td>
<td>32.1%</td>
<td>32.6%</td>
</tr>
</tbody>
</table>